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Innovation in practice: Learning in a technological environment.

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Abstract

Geo-Logo 1 was designed as an environment to support the learning of geometry. The research reported in this paper concerns the performance and strategies of children working in one of three gender pairs (girls, boys, and boy/girl) in Geo-Logo tasks that form a complete curriculum teaching and learning sequence. The case studies to be presented reveal that the children show a high level of engagement and learning in the Geo-Logo environment. They engage in complex problem-solving that requires them to integrate previously acquired mathematical knowledge with strategies, in a new and dynamic way.

Introduction

Logo was originally created to provide a conceptual framework for the development of mathematical ideas. A major feature of the turtle graphics aspect of Logo was related to the fact that it constituted an environment in which young children could use a transitory object (the turtle) to think with and in doing so become the owners and users of a powerful tool that would enhance their thinking skills and empower them to view and use mathematics in new and exciting ways (Papert, 1980).

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Geo-Logo is a variation of Logo and was designed as an environment to support the learning of geometry that would both promote and encourage active exploration and investigation of concepts. This is also true of all the units that make up the Investigations 2 curriculum, of which it is a part. Geo-Logo enables young children to work with the Logo turtle in ways that are significantly different from the initial versions of Logo. Most noticeably it provides "tools" that assist the learner to operate in the environment. The Geo-Logo screen format allows children to develop code and watch the turtle draw each command as it is typed in a window that is adjacent to the drawing. Additionally, the "teach" tool can be selected to create a procedure once they are satisfied with the code that they have created. There are also features that assist children to create items. For example, a "turtle turner" enables them to measure turns on the screen and a "grid overlay" assists in positioning items that have been developed.

The present research focused on one curriculum unit entitled Turtle Paths which involved Year 3 children in both geometric, numeric and problem-solving activities over a period of eight weeks. Basic to the unit was the notion that young children learn most effectively when they actively construct ideas and when they are given the opportunity to engage in tasks that are both meaningful and appropriate to their developmental level.

The concept of a path as a record of tracing the movement of a point has been found to be conducive to the development of knowledge about two-dimensional shapes and their properties when it was incorporated into activities that stressed both the perceptual and physical aspects of paths (Clements & Battista, 1994). For example, children who initially described visual aspects of a two dimensional shape, such as rectangles, later described them in terms of their salient aspects and stated the procedures that created them. This represents a shift in conceptualisation in the Van Hiele (Crowley, 1991; Pegg, 1985) model from level 0 to levels 1 and/ or 2. That is, from visual to descriptive / analytic. Such a shift can be represented in comments related to a child's description of a rectangle, for example, in terms of its global components: "put 2 lines like that......put 2 lines about .....as far away as you think. Put 2 lines on to the 2 lines - join them up." to a description that incorporated the specific attributes that constitute a rectangle. "It's a 4 sided figure. It has to have 90 degree turns and they have to be ....a closed shape."

This led to the view that "Logo experience encourages students to view and describe geometric objects in terms of the actions or procedures used to construct them (Clements & Battista, 1994 p.175) Additionally, the activities developed as part of the Turtle Paths unit required the children to consider the attributes of various two-dimensional shapes in order to create accurate instructions that would construct them. At

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the same time the teacher/ researchers scaffolded the children's learning by questioning them and asking them to articulate aspects of the properties of the shapes that they had created. The teacher/ researchers also encouraged the children to explore the shapes that they had created, by extending the activities in a variety of ways. It has been shown that such interactions are important to learning (Clements & Battista, 1994 p.183) and indeed, " may be unique in providing scaffolding that allows students to build on their initial intuitive visual approaches and construct more analytic approaches. In this way, early unsophisticated non-standard concepts and strategies may be precursors of more sophisticated mathematics" (Clements & Battista, 1994 p.183).

It has also been suggested that knowledge about both perceptual and physical aspects of two-dimensional shapes and their inter-relatedness can also enhance understanding of measurement concepts (Clements & Battista, 1992). When children were given the opportunity to explore and investigate in a Logo environment designed to encourage them to manipulate units and think about the idea of changing measurements of unit, they were found to be more accurate in specific measurement tasks than children who had no such experience (Noss, 1984)

Thus, the Geo-Logo environment and the Investigations curriculum provided the medium in which young children's development and understanding of specific mathematical ideas related to paths and the generation of two dimensional shapes is discussed.

An overview of the sequence of activities that the children participated in over a period of 8 weeks is provided in Figure 1. The activities were contained in a unit from the Investigations curriculum entitled "Turtle Paths" The focus of this paper is the children's problem-solving and application of mathematical ideas related to two of the tasks; missing measures and 200 steps which were completed in consecutive weeks of the research.

Figure 1
Sequence of activities in Investigations:
Turtle Paths.

The Turtle Paths unit was designed to provide the opportunity for students to develop their ideas about paths and how paths as a record of movement could result in the creation of a number of two dimensional shapes. The unit was based around three main components:
1. Paths and lengths of paths
2. Turns in paths
3. Paths with the same length: Isometric exercises

It engaged the children in discussion pertaining to the concept of a path, creating paths with a partner in the playground through to playing games in which the path as a record of movement were

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instrumental, and the generation of code or procedures that could draw simple shapes. Additionally, a face creating program and a free choice project developed by the children were incorporated in order to give the children the opportunity to explore with their new found knowledge in a meaningful context.

The two activities that will discussed in this paper are the missing measures and 200 steps. They occurred in weeks five and six of the research.

The missing measures activity was a task within the second investigation; turns in paths. It consisted of both an off and on computer component. In the off computer task the children had to write the Logo commands that would complete a given diagram (Appendix 1.). They then went to the computer to enter the commands that would draw each item.

The 200 steps activity required the children to consider how many rectangles they could construct with Geo-Logo that would have a perimeter of 200 steps. Both activities required the children to analyse geometric figures and use number in order to complete the task directions.

Method.

Sample

Fourteen children, nine boys and five girls, from a suburban primary school participated in the study. Their mean age was 7 years and 9 months with a range from 7 years 4 months to 8 years 5 months. The children were paired on the basis of their performance on the Coloured Progressive Matrices (CPM) test as it was considered to be important that children of similar intelligence be paired to prevent one member dominating the interaction. The creation of pairs in this way resulted in four boy pairs, two girl pairs and a mixed gender pair. The children were members of a composite Year 2/3 class with 8 children from Year 2.

Procedure

All instruction and activities took place in an area that was an extension of the classroom where the children were videotaped as they participated in the activities. Additionally, a multi gen recorder was used to videotape each move on the computer screen that the pairs of children made in order to achieve task solution. For the purpose of data analysis the two videos were mixed in order to maximise the information that was obtained and to facilitate a comparison of performance and strategies deployed. Each section of the unit was introduced by a teacher/ researcher and then the children were required to participate in a follow up activity. The tasks consisted of both on

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and off computer activities. Figure 1 reveals that the research occurred over a period of 8 weeks and contained both a pre and post observation phase in which the children were required to complete requisite mathematical questions that were implicit to the tasks in the unit. For each new activity the game or notion was explained to the whole groups with time for exploration and questions and then the children worked in their pairs off the computer before going on to the computer to complete the task requirements.

Results and Discussion

Missing Measures

In the off-computer component of the missing measures activity the children were asked to record the code necessary to complete each of six items (Appendix 1.) They were reluctant to do this and some would only record the commands, that would complete each item. They argued that the commands were already on the paper. They meant that each diagram had a label that indicated the length of the sides that were complete. No labels for turns were provided. For the first three items all of the children immediately recognised that the missing component had to be the amount that would make the side equal to its corresponding side. This meant in the first two items that they realised that opposite sides of a rectangle had to be equal and the turns had to be 90 degrees. In the third figure, an equilateral triangle they reasoned to complete the final side the amount had to be 80 (turtle steps) as the other two sides were 80 and this one had to be the same. All the children used a counting on strategy after they had articulated the reasons why the side in question had to be a particular amount. For example:

Melitta: This whole side has to be 100, like that one (pointing) so it's 25 more. Then the turn is right 90 and this side will be 30 like that one (pointing).
T: How did you know it has to be 100?
Melitta: because it's a rectangle!

Consequently the task of entering the code for these items on the computer was straightforward for the children. It was interesting to note that they had no difficulty with remembering the measures for the turns, both for the rectangles and the equilateral triangle, even though they were not provided on the sheet. The activity immediately preceding this one required them to create the code for an equilateral triangle and the 90 degree turn was the focus of the initial path activity in the unit. It would seem that they recalled this information and used it for the missing measures tasks.

Figure 2
Missing Measure: Cody and Shaun

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The fourth item was called a factory All of the three children who attempted to do this on the sheet thought that the missing distance

would be 40. When asked "why?" They said that it was 20 and 20. When they entered the amount they were obviously surprised that it did not work, but they immediately recognised that the gap that was left was 20 because of "the third step".

The fifth item proved to be much more challenging for the children. Only four pairs attempted this on the sheet and they all thought that the vertical measure of the step would be 18. Three pairs thought that the final step would be 20, the other pair thought it would be 25. All justified their responses in terms that it was "bit bigger" than the other steps. The decision for these amounts was thus based on a visual approximation strategy and not on computation based on knowledge of the measure of corresponding sides.

When the children entered the commands on the computer all the pairs entered 18 for the first two vertical step components. Two pairs entered 20 for the final step, another pair used 24 (Figure 2), and four pairs used 25. All of the pairs thought that the base of the steps would be 60 on the basis that the first side was 60. This was interesting because it meant that they had not generalised the strategy that they had utilised in the previous item to create the final side by computing the amount based on the three constituent parts that it was equal to. Once they realised that the line was a bit too long they just took off two or three steps based on their perception of the visual effect and were content that the final product resembled the item on the sheet. The researcher questioned one pair about the effectiveness of this strategy by hiding the turtle with the HT command and showing them that the final path was indeed too long they immediately changed the final command to 56, 55, and finally 54 until they were happy that it was "in the corner". When asked if it was exactly like the one on the sheet they were confident that it was! The researcher then asked the children how they knew that the first two steps were 18 and the final one 25 and they explained that the first two were 18 (down) because they were 18 across and that the last one was a bit bigger so they used 20 and that was not enough so they tried 25 and it worked. After a similar line of questioning, Angela and Denielle were told that each of the vertical steps were 20 because the height of the "steps" was 60. They thought that this was wrong, but when the researcher entered the commands to illustrate the point but they said that was just another way to do it! In trying to encourage them to adopt a more accurate strategy to determine the measure of the base of the "steps" the pair were told that one possible way to work this out was to say it was the same as three lots of 18 because it was the same as those three measures. They both looked surprised and then

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said "Oh Yes!" and then worked it out by adding 18 + 18 + 18 on the calculator to arrive at 54. When asked if they could change their code to accommodate these changes they seemed reluctant to do so but as they were always eager to please they did so by identifying the commands that generated each distance move and changing them with ease. At the end they exclaimed "There!" and added, "It really looks the same as before!".

For the final item, the children had to complete on partially drawn side, decide on the amount of a turn and draw the base of the "house". Only one child, Courtney, attempted this on the "planning" sheet, and she omitted the final side. Courtney succeeded in recording all the correct moves even the RT 30 that was required, after the FD 25 so that the roof of the house was "straight". When asked how she knew that it was RT 30 she said "because we did that in the triangles!" This was a reference to the previous activity where they were required to create the code to draw an equilateral triangle. After they had completed this task they were dissatisfied with the alignment of the triangle and

wanted it to be "straight". All the pairs experimented with the alignment of the triangle and eventually discovered that in order for this to be achieved the first command had to be RT 30. None of the pairs exhibited any difficulty with entering the commands that would draw the house as was shown on the sheet. When they came to the final vertical side, five pairs entered forward 45 and then added on 20 reasoning that it had to be 65 because it was the same as 40 and 25 "over there", meaning the two vertical paths on the left side of the house. It was interesting that this was such a salient feature to these children and the nature of the numbers and the simplicity of the calculation involved, the fact that it could be done mentally, made the process relatively easy for them. They seemed to be much more reluctant to use this strategy in the previous item where the numbers were not rounded to 5 or 10 and the amount of sides to be added together was one more. Two boy pairs however reasoned that as the side had to be 65 they could enter that as one command! The initial activities in the unit had encouraged the pairs to be economical in their moves and it was apparent that these boys had generalised this principle so as to use it in the drawing of the house. The base of the house proved to be more of a challenge for the children in that they seemed to be reluctant to calculate in order to obtain the exact measure involved, but preferred to use a trial and error strategy. Only one pair, said that it had to be 75 because it was 45 and 30. They did this while pointing to the relevant segments with which it corresponded. Three pairs included both amounts for the roof of the house (45 + 45) and the vertical and horizontal sides immediately before the roof (25 + 30). They were most surprised that they could have made such an overestimation. One pair immediately halved this, made an error to get the answer of 75, which was in fact the exact amount required. A classic example of a serendipitous discovery!

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Other pairs tried varying amounts until they got the turtle to meet the first vertical side of the house. They used the HT command to make sure that the turtle was in the corner! This strategy was important because it indicated that the pairs felt confident enough to explore in this way in the Geo-Logo environment. It was only possible because in this version of Logo changes in code result in corresponding changes in the graphics without the necessity of starting from the beginning. This design feature is one of the most empowering features of Geo-Logo because it encourages young children to explore without having to modify the whole design. It was interesting to note that most of the children felt confident mentally adding two numbers but as soon as a third was introduced they asked for the calculator.

Thus, the missing measures activity encouraged the children to think about the relationships between the sides of given figures by requiring the pairs to create the code that would result in their production. Central to the process was providing them with the opportunity to share their strategies with each other and the researcher. This gave the children the chance to articulate their own strategies and reasoning processes and also to listen to the different ways that others had used that resulted in the same final product.

However it was also apparent that the children basically used similar types of strategies and that these fell into 2 categories. Firstly, there were those who relied on visual approximation. An example of this was when they reasoned that a length was 60 "because it looked like it" or that it was " 40, because that (pointing to 40 on another figure) was 40 and this looked the same size." Naturally this strategy was sometimes successful even though it was perceptually bound! Secondly, there were those children who used comparison with other sides and (effective) computation to calculate the length of a given path. Thus they said "This has to be 60 because it is the same as these and they are 20,20,20" or "it's 65 because it's 40 and 25, like that". It was also apparent that the use of these strategies was not consistent across all the items. Some features seemed to encourage the former strategy while others seemed to me more conducive to the application of the operations, in this study addition and subtraction (more rarely) but never multiplication. So, for instance in item 5, when Angela and Denielle were questioned about the length of the base they realised that it was three lots of 18, but chose to add them rather than multiply even though they had a calculator.

200 steps

In the 200 steps activity the children were required to determine how many different closed paths they could make that had perimeters of 200 turtle steps and four 90 degree turns. In order to do this they were given paper and asked to draw and label each side of the shapes with the appropriate measure. Calculators were available for the children

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so that they could check if they had achieved the desired amount of 200. The children worked on the task individually and then came together in their pairs in order to enter their various sized rectangles in Geo-Logo. All of the children started with a 50 by 50 square and when we discussed if this was a rectangle it was agreed that it was since it had the basic components that were required in a definition, that is, it had four 90 degree turns, it had two sets of sides that were the same length and "opposite" and "straight like railway lines". In using these descriptions it was apparent that the children meant that they were parallel but had not been introduced to the term as yet. The next most used numbers for rectangles were 80 by 20 and 75 by 25. Four children used 90 by 10, five 60 by 40 , two 70 by 30. Only three children, Ryan, Jesse and Denielle used combinations that incorporated numbers without 5 or 0 in the ones place. Jesse experimented with 55 by 45 and 88 by 12, Ryan with 66 by 31 and Denielle with 76 by 24. In order to generate these combinations they added numbers for the longest two sides together, counted on to make 200 and then halved the number.

Two pairs, Angela and Denielle and Alex and Adam entered commands that drew " a kite". Angela and Denielle were asked if theirs was a rectangle and immediately answered, "Yes, but it's on it's side!" They could cite the features that made it so; it was a closed shape with four sides and four corners. When questioned about the size of the angles they said that they "were not 90 , but that did not matter!". We pointed out that rectangles had to have 90 degree angles but they answered us confidently assuring us that this was a "special one" because it didn't have 90 degree turns, but it had sides like "normal" rectangles that added up to 200 (they had used 70 and 30). Alex and Adam used 60 and 40 and remained convinced that they had drawn a special rectangle with different corners. Each of these two pairs had used the "turtle turner" in order to determine the size of the turns required to create their parallelograms.

It was interesting to note that when the pairs of children shared their rectangles and entered them on to the computer they seemed to be less engaged in this task than any other in the sequence of activities. It is thought that this was basically because the task was not engaging their interest since by the time that they came to enter the commands it was so straightforward as to be mundane. In retrospect it would have been beneficial to introduce discuss the structure of the procedures at this point in time and attempt to find commonalties that led to a discussion of the possibility of creating a universal procedure that would draw any rectangle, thus introducing the concept of a variable in a meaningful way.

Pre and Post tests

As previously stated the children participated in pre and post test that contained items pertaining to specific mathematical skills and

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processes. It is not possible to discuss all the items in relation to the present paper but it is apparent that some interesting trends emerged from the data.

The most salient of these was related to the children's ability to answer a question which required them to determine what each side of a rectangle, square and equilateral triangle would be if the perimeter was to be 12 (Appendix 2).

Before the research began only three of the 14 children could calculate the perimeter of each of the shapes correctly. An additional four could correctly solve the perimeters of the square and triangle but not the rectangle. In the post test phase all of the children correctly answered all parts of this item.

Another interesting item was the one that asked the children to state what half of 90 and 120 were and to explain how they had worked it out. In the pre test four children we able to do this while two could correctly state and explain half of 120 and one did the same for 90. In the post test an additional six children could calculate and explain how they had determined the halves while one child said that he did not know when he had previously correctly answered the items in the pre test phase.

Furthermore, the pre test (and post test) revealed that the children could not calculate 40 x 3 or 60 divided by 3 when they were presented in symbolic form. Thus, it was not surprising to find that they did not incorporate these operations as strategies for solving the missing measures problems.

Two items in the pre/ post interview that were associated with activities in the turtle paths units were related to stating the missing measures in two diagrams. These are shown in Appendix 3. In the pre test six children were able to correctly identify the length of the sign as being 40 and of these only one used addition and counting on to determine his answer. The other five children all said that it was 40 because it looked like it! Of these two used their fingers to justify the amount saying that 30 was "this much" so the sign had to be 40! In the post test the number of children who could answer this item had risen to nine but what was more interesting was that of these six calculated the answer by saying that it was 100 take away 60. When asked to elaborate on how he had obtained these numbers Ryan offered the following explanation: "The whole thing has to be 100 and you already have 30 add 30 which is 60 used up. So the sign has to be 40 more. 100 take away 60 is 40".

In the next missing measures item the children were presented with the drawing of a house and asked to state the lengths of three sides labelled a, b, and c. In the pre test all the children could correctly state the measure of a and b while 10 ascertained that the missing

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measure for c was 20. When asked how they worked it out two said it was 20 because 20 and 10 were 30 and it had to be 30 to match the top (pointing). One child said she guessed and the remaining seven all justified the amount in terms of it looking like 20. For example, Angela said:" it's bigger than 10 and smaller than 30 so it has to be 20 'cos it looks about it".

In the post test all the children correctly stated that the missing part for c was 20 and, apart from one girl, provided justifications in terms of it being the difference between 30 and 10, which was 20.

A item of relevance here are the children's descriptions of how they would describe a square, rectangle and triangle to another person on the phone. Before the research it was evident that the children considered each in terms of the number of sides and corners. Whereas, at the completion of the unit six children gave more elaborate answers that seemed to reflect their experience with the Geo-Logo tasks. For example, in relation to triangles:

Angela
pre: 3 exactual sides and it has no gaps in it.
post: It has got 3 straight sides, it does not have to be equal, it's got 3 corners (points) and they've got 3 right turns

Courtney
pre: it's got 3 corners and 3 straight lines
post: a triangle has 3 straight sides, 3 corners, and it's not a solid shape it's a flat shape......and all the sides are the same size ....and they are joined together.

Shaun
pre: It was like a "V" and then another straight line form one tip of the "v" to the other.
post: Its got 3 sides and it has to have straight sides and 3 corners and it's a closed path

Melitta
pre: "It's got 3 sides and it can be all different shapes and the sides are all the same size"
post: "It's got 3 sides and 3 turns and it's not open it's a closed shape.

Additionally, mid-way through the research when asked to state how they knew a particular shape was a triangle, nine of the children identified the fact that it had three sides, three corners and was a closed path as their rationale and the remaining five included the first two features. At this point 11 of the children could also correctly write the procedure that would draw a triangle with paper and pencil.

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Conclusions.

The examples from the two tasks indicate that young children can explore geometric concepts in a meaningful and engaging way while investigating in a technologically based learning environment. In doing so, they were able to actively construct and modify ideas because the dynamic and interactive nature of the environment afforded them the opportunity to coordinate spatial and numeric concepts to solve novel problems. This highlights that one way to make mathematics more meaningful to learners would be via activities that encourage connections in nontrivial problem-solving contexts and require them to employ mathematical knowledge and analyses in a vibrant way. The choice of paths as a unit of study seemed to be a useful springboard to the study and understanding of two dimensional shapes and their properties. The aspect of determining the measure of specific paths encouraged children to reflect on visual and numeric properties of paths and the relationships between different paths and the turns made between them posed some interesting challenges to the children's thought processes. When learners have acquired a range of mathematical skills, processes and knowledge it is interesting to investigate how they are used in a variety of different contexts. The present research has sought to highlight some of the ways in which young children use mathematical processes in innovative and creative ways and how they can articulate their reasons for doing so.

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